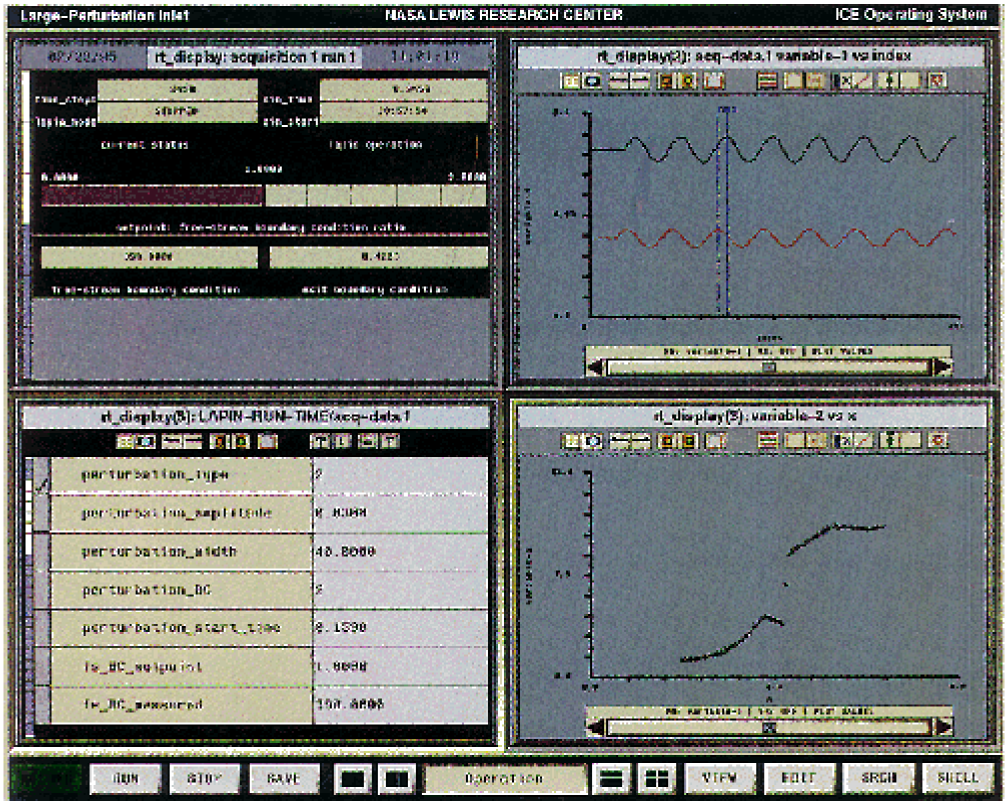
User Interface Developed for Controls/CFD Interdisciplinary Research

The NASA Lewis Research Center, in conjunction with the University of Akron, is developing analytical methods and software tools to create a cross-discipline "bridge" between controls and computational fluid dynamics (CFD) technologies (ref. 1). Traditionally, the controls analyst has used simulations based on large lumping techniques to generate low-order linear models convenient for designing propulsion system controls. For complex, high-speed vehicles such as the High Speed Civil Transport (HSCT), simulations based on CFD methods are required to capture the relevant flow physics. The use of CFD should also help reduce the development time and costs associated with experimentally tuning the control system. The initial application for this research is the High Speed Civil Transport inlet control problem.

A major aspect of this research is the development of a controls/CFD interface for non-CFD experts, to facilitate the interactive operation of CFD simulations and the extraction of reduced-order, time-accurate models from CFD results. A distributed computing approach for implementing the interface is being explored. Software being developed as part of the Integrated CFD and Experiments (ICE) project provides the basis for the operating environment, including run-time displays and information (data base) management. Message-passing software is used to communicate between the ICE system and the CFD simulation, which can reside on distributed, parallel computing systems. Initially, the one-dimensional Large-Perturbation Inlet (LAPIN**)** code is being used to simulate a High Speed Civil Transport type inlet. LAPIN can model real supersonic inlet features, including bleeds, bypasses, and variable geometry, such as translating or variable-ramp-angle centerbodies. Work is in progress to use parallel versions of the multidimensional NPARC code.

The figure shows a snapshot of one display configuration of the Controls/CFD user interface during interactive operation of LAPIN. The CFD code execution mode is controlled by the **RUN** and **STOP** buttons at the lower left of the screen. The **RECORD** button permits the user to start or stop recording flow field information at any time. The **SAVE** button enables users to save the recorded information as a permanent file in the ICE data base. With LAPIN, execution and display updates both occur in near-real time. The upper left quadrant shows the code execution status and slider bars for interactively controlling the inlet and exit boundary conditions (only the slider bar for the free-stream temperature set point is visible in this screen).



Controls/CFD user interface.

In this case, LAPIN is simulating the response of the inlet without control, while operating at a free-stream Mach number of 2.35 and an exit Mach number operating-point value of 0.4223. The inlet is being perturbed by a 40-Hz sinusoid in the exit Mach number with a 3.0-percent zero-to-peak amplitude. The lower left quadrant shows some of the variables that can be changed interactively to affect the LAPIN execution (e.g., variables specifying the inlet perturbation). The upper right quadrant shows time histories of two inlet variables--Mach number at the exit (lower curve) and Mach number at a location downstream of, but near, the normal shock. Phase shift between the two signals can be measured by the two vertical lines, which are manually positioned by clicking on the horizontal axis. (Horizontal lines for determining amplitude response can be positioned by clicking on the vertical axis.) The lower right plot shows the "instantaneous" axial static-pressure distribution in the inlet. The nearly discontinuous jump in pressure indicates the location of the normal shock.

Reference

1. Cole, G.L., et al.: Computational Methods for HSCT-Inlet Controls/CFD Interdisciplinary Research. AIAA Paper 94-3209, 1994.